Accepted Manuscript

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PII: S0301-0511(19)30077-8
DOI: https://doi.org/10.1016/j.biopsycho.2019.01.017
Reference: BIOPSY 7657

To appear in:

Received date: 6 March 2017
Revised date: 10 September 2018
Accepted date: 29 January 2019

Please cite this article as: Sanchez-Lopez A, Everaert J, Van Put J, De Raedt R, Koster EHW, Eye-gaze contingent attention training (ECAT):Examining the causal role of attention regulation in reappraisal and rumination, *Biological Psychology* (2019), https://doi.org/10.1016/j.biopsycho.2019.01.017

Eye-gaze contingent attention training (ECAT):Examining the causal role of attention regulation in reappraisal and rumination

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Highlights

- We examined the role of attention mechanisms in emotion regulation processes
- A novel eye-gaze contingent attention training (ECAT) was used
- The training led to attention regulation implementation, leading to transfer effects
- Attention changes led to changes in reappraisal, negative emotions and rumination
- The ECAT is an important step towards personalized and advanced attention training

Abstract

This study used a novel eye-gaze contingent attention training (ECAT) to test the prediction that attention regulation is involved in reappraisal and rumination. Sixty-six undergraduates were randomly assigned to either the control or the active training condition of the ECAT. Active ECAT comprised training in allocating attention toward positive words to efficiently create positive interpretations while receiving gaze-contingent feedback. Participants in the control condition freely generated interpretations without receiving gaze-contingent feedback. Active ECAT resulted in: 1) more sustained attention on positive information, in turn predicting greater reappraisal success to down-regulate negative emotions, and 2) larger reductions in state rumination after viewing negative scenes. Our results highlight the importance of considering attention mechanisms in understanding (and treating impaired) emotion regulation processes. These findings provide an important step toward the use of personalized attention training to build resources of resilience.

Key words: Selective attention; attentional control; reappraisal; rumination; negative emotions; attention bias modification

Introduction

Attention mechanisms are postulated to play an important role in both vulnerability and resilience for affective disorders (e.g., Gotlib & Joormann, 2010; Raedt & Koster, 2010). Depressed individuals are characterized by reduced attention toward positive information and sustained attention for negative information, in contrast to healthy controls, who tend to show preferential attention towards positive information (Armstrong & Olatunji, 2012; Peckham, McHugh, & Otto, 2010). A growing literature suggest that these individual differences in attention mechanisms are at the basis of the inefficient use of emotion regulation strategies that characterize affective disorders (Joormann & Stanton, 2016). Consequently, there has been a recent upsurge of research aimed to identify and target specific attentional mechanisms involved in the efficient use of emotion regulation strategies.

One of the most powerful strategies to regulate negative mood states is reappraisal, namely reinterpreting distressing events to decrease its emotional impact (Gross, 2014). Successful reappraisal has various beneficial outcomes, including increased positive and decreased negative mood (Augustine & Hemenover, 2009; Webb, Miles, & Sheeran, 2012), enhanced stress recovery (Jamieson, Mendes, & Nock, 2013), as well as better interpersonal functioning (Gross & John, 2003). Importantly, attention mechanisms have been proposed to be causally related to reappraisal ability and its impact on negative emotions (Joormann & D'Avanzato, 2010; Sheppes, Suri, & Gross, 2015). Consistently, cross-sectional studies using eye-tracking technology to monitor attention have shown that the effectiveness to reappraise negative scenes is related to lower attention towards the scenes' negative areas (Manera, Samson, Pehrs, Lee, & Gross, 2014; van Reekum et al., 2007). Specifically, recent research indicates that successful down regulation of negative affect via reappraisal is associated with initial attention towards negative areas, allowing for their initial processing, followed by subsequent shifts away from them (Strauss, Ossenfort, & Whearty, 2016). Therefore, the ability to disengage attention from negative information, allowing shifting attention toward alternative positive sources of information, might be at the basis of successful reappraisal.

The causal role of these attention mechanisms in reappraisal has only been recently tested (Sanchez, Everaert, & Koster, 2016). Sanchez et al. (2016) developed a novel eye-gaze contingent attention training (ECAT) in which participants were trained to regulate attention allocation (intentionally disengage attention from negative information in favor of processing positive information), in order to generate positive self-referent interpretations. Trainees received: 1) online gaze-contingent feedback when their attention was captured by competing negative and positive words, as detected by an eye-tracker, in order to facilitate top-down regulation of attentional processing (i.e., intentionally disengage attention from negative words when they were fixated and maximize sustained attention on alternative positive words), and 2) feedback on performance between blocks (i.e., explicit information on individuals' time attending towards positive vs. negative stimuli), in order to increase awareness of emotional attention biases to maximize attention regulation in subsequent trials (see also Bernstein & Zvielli, 2014; Schnyer et al., 2015). Sanchez et al. (2016) showed that active ECAT, in comparison to a control condition where participants did not receive gaze-contingent feedback, led to attention regulation (increased fixation durations towards positive over negative stimuli during the training). In turn, larger attention regulation during training predicted larger positive attention biases in a transfer reaction time-based attention task (i.e., the dot-probe task; MacLeod, Mathews, & Tata, 1986), which, in turn, predicted improvements in the ability to use reappraisal and decreased negative emotions (i.e., active ECAT → higher attention regulation → higher positive attention bias →

improved reappraisal → lower negative emotions). Results of this study highlight the potential of considering attention mechanisms in understanding (and treating impaired) emotion regulation processes. Yet, further research is required to clarify: a) the specific attention mechanisms targeted by ECAT, and b) their possible transfer effects to other emotion regulation strategies.

Specific attention mechanisms targeted by ECAT. Sanchez et al. (2016) assessed attention bias changes with a standard dot-probe task with competing positive and negative words. Attention bias in this task is indexed through a composite measure (i.e., subtraction of reaction times to detect probes when they replace negative words from when they replace positive words). Therefore, it is unclear whether indirect effects of ECAT in reappraisal were due to improvements in mechanisms of attentional disengagement from negative information, increased sustained attention towards positive information or both. We aimed to clarify this question by measuring ECAT transfer effects to attention biases with a novel eye-tracking paradigm, the attentional engagement-disengagement task (Sanchez, Vazquez, Marker, LeMoult, & Joormann, 2013), which allows to separately index processes of gaze disengagement from positive and negative information. This allowed to establish whether ECAT transfer effects would be observed in: 1) faster latencies to disengage visual attention from negative information, 2) longer latencies to disengage visual attention from positive information, or 3) both attention operations. In line with Sanchez et al. (2016), we first expected that the ECAT would lead, in comparison to a control condition, to an implementation of attention regulation, namely increased attention towards positive over negative information during the training (i.e., Hypothesis 1; H1: condition → attention regulation). Then, we expected that higher attention regulation during active ECAT would transfer to modification of attention mechanisms measured in the engagement-disengagement task (i.e., H2: condition → attention regulation → attention bias changes), and that targeted attention bias changes would subsequently lead to improvements in reappraisal ability (i.e., H3: condition → attention regulation → attention bias changes → reappraisal improvement), as found in Sanchez et al. (2016). Finally, we expected that the pathway in H3 would account for an indirect effect of the training on down-regulation of negative emotions (i.e., H4: condition → attentional regulation → attention bias changes → reappraisal improvement → decreased negative emotions; Sanchez et al., 2016).

Common or specific transfer effects of ECAT in reappraisal and rumination. The present study also aimed to clarify whether attention regulation, as trained with ECAT, also play a causal role in the use of other emotion regulation strategies, such as rumination. Rumination involves a passive repetitive focus on causes, implications, and meaning of experienced sad mood and distress (Nolen-Hoeksema, Wisco, & Lyubomirsky, 2008). This response style is considered a maladaptive process, since it augments sad mood and negative thinking in response to negative events (Nolen-Hoeksema et al., 2008). Moreover, habitual use of rumination in response to negative events is inversely related with the habitual use of reappraisal strategies (D'Avanzato, Joormann, Siemer, & Gotlib, 2013) and is predictive of affective disorders' onset and maintenance (Nolen-Hoeksema et al., 2008). The possibility that both reappraisal and rumination strategies share common attention mechanisms has been highlighted in recent research. Recent research has shown that impaired inhibition of negative processing is associated with both reduced habitual use of reappraisal and increased habitual use of rumination (e.g., Cohen, Daches, Mor, & Henik, 2014). Furthermore, such inhibition deficits moderate the impact of both rumination and reappraisal strategies in daily life's emotional experience (e.g., Pe et al., 2013). Therefore, in the current study, we tested whether attention regulation implemented via ECAT transfer to both improvements in reappraisal ability (Sanchez, Everaert, et al., 2016) and to decreases in state rumination. We expected that attention regulation implementation as the result of receiving active ECAT would be predictive of improvements in state rumination in response to viewing negative scenes (i.e., H5: condition → attention regulation → state rumination decrease).

Methods

Participants

A sample of 66 undergraduates (mean age: 23.30 years, SD = 5.44) was recruited via the participant pool at Ghent University. All participants (17 males and 49 females) had normal or corrected to normal (using glasses or contact lenses) vision. Participants were paid 20 euro. The institutional review board approved the study protocol.

Design Overview

Figure 1 depicts the sequence of tasks. The sequence was similar to the one employed in Sanchez et al. (2016). Concerning the ECAT procedure, all participants completed a baseline phase followed by either an active training or control procedure that was determined by random assignment. Before and after completing the ECAT, participants completed the attentional engagement-disengagement task, and an emotion regulation task assessing reappraisal ability and negative emotion level. After completing the emotional regulation task, participants also reported the level of ruminative thinking experienced during their performance. Furthermore, before completing the pre-training assessment, participants were also asked to fill out a questionnaire package including self-report measures of depressive (Beck Depression-Inventory-II, BDI-II; Beck, Steer, & Brown, 1996) and anxiety symptoms (Trait Anxiety Inventory, STAI; (Spielberger, 1983), trait rumination (RRS; Treynor et al., 2003) and reappraisal (Emotion Regulation Questionnaire, ERQ; Gross & John, 2003), and trait levels of resilience against adversity (Resilience Scale, RS; Wagnild & Young, 1993), as well as to perform an attentional control task assessing executive functions of inhibition and switching (i.e., the emotional mixed antisaccade task). Pre-training self-reports and performance on the attentional control task were used to further test potential predictors of ECAT effectiveness (see full details in the Supplementary material). The full experimental session lasted 110 min.

ECAT Procedure

The ECAT procedure was identical to Sanchez et al. (2016), based on a modified version of the Scrambled Sentences Test (Everaert, Duyck, & Koster, 2014). The whole procedure comprised 69 trials, including 60 emotional and 9 neutral scrambled sentences which were all self-referent and 6 words long. The critical target words of the scrambled sentences were matched on word length and word frequency (see Sanchez et al., 2016). The training procedure lasted approximately 25 minutes. Figure 2 depicts the sequence of training phases.

Baseline phase. Each trial in the baseline phase involved the presentation of an emotional scrambled sentence (e.g., “am winner born loser a I”), displayed following the detection of a visual fixation in a cross (left-aligned to elicit left-to-right reading). While the item was on-screen, participants were instructed to unscramble the sentence to form a grammatically correct and meaningful statement using five of the six words as quickly as possible and within a time limit of 8000 ms (e.g., “I am a born winner”). Eye movements were monitored via eye tracking while participants unscrambled the sentence. Upon completion, they pressed a button and reported their solution using the numbers linked to the words in the scrambled sentence.

After a 3-trial practice phase with neutral scrambled sentences, the baseline phase comprised 12 emotional scrambled sentences, presented in random order. Participants then completed 6 filler neutral scrambled sentences before starting the modification phase.

Modification phase. Participants completed 8 blocks of 6 randomly presented emotional scrambled sentences. Eye movements were again registered while participants unscrambled the sentences. Whereas the task in the control condition was identical to the baseline phase, the training condition included several manipulations. First, participants were instructed to unscramble all sentences into *positive self-statements* (Sanchez, Everaert, De Putter, Mueller, & Koster, 2015) and to focus attention on positive words, as this would help to identify and form positive meanings more efficiently. Second, participants received online gaze-contingent feedback on their attentional deployment while unscrambling the sentences. A red or green square respectively framed the negative or positive target each time the eye-tracker detected a fixation. Finally, after each training block, participants received feedback comparing their gaze behavior during the last block (e.g., “You looked 54% of the time at the positive word”) with gaze behavior during the baseline phase (e.g., “You looked 42% of the time at the positive word”). This procedure intends to increase awareness of the progress made in the training condition compared with baseline.

Dependent variables. In line with prior work (Everaert, Duyck, et al., 2014; Sanchez et al., 2016), an index of attention bias for processing positive vs. negative material was computed by dividing the total fixation time on positive words by the total fixation time on emotional (positive and negative) words, separately for each training phase (i.e., baseline phase vs. modification phase). These indices served to test the hypothesis (H1) that participants would implement attention regulation in the training condition (i.e., significant increases in attention bias to positive over negative material from the baseline to the modification phase, as observed in Sanchez et al., 2016).

Transfer of training

Attention biases. The engagement-disengagement task (Sanchez et al., 2013) indexed separate attention mechanisms of attentional disengagement from emotional (i.e., positive, negative) information. The task comprised 144 randomly presented trials. Twenty-four disgusted, happy, and neutral models (12 men and 12 women depicting each of the three emotions) were selected from the Radboud Faces database (RaFD; Langner et al., 2010), based on data from a previous validation (Langner et al., 2010). Further details on characteristics of the stimuli set can be found in in Sanchez, Vanderhasselt, Baeken, & De Raedt (2016).

In the basic design of the task (Sanchez et al., 2013), each trial started with the presentation of a blank screen for 500 ms, followed by the display of a central fixation cross. Immediately after the participant made a visual fixation in the cross area, a pair of faces (one negative or positive face vs. the neutral face of the same actor) was presented for a pre-specified amount of time (standard time: 3,000 ms). After the free-viewing time was finished, a “wait for fixation” period was introduced, where stimuli presentation did not continue until participants fixated on a given face (pre-specified in each trial) for 100 ms. Once this occurred, a frame consisting of either a square or a circle appeared surrounding the opposite face. Participants were then instructed to direct their gaze toward that frame as quickly as possible and press one of two response keys on the keyboard to indicate the frame type. This task has proven to reliably index mechanisms of attentional engagement with emotional information (i.e., time to move gaze from a neutral face to a subsequently framed negative/positive face) and attentional disengagement from emotional information (i.e., time to move gaze from a negative/positive face to a subsequently framed neutral one; see Sanchez, Vanderhasselt, et al., 2016; Sanchez et al., 2013).

The task version in the current study was modified to test whether specific trained attention regulation in the ECAT procedure transferred to: a) faster attentional disengagement from negative material when positive material is also available, and/or b) increased attention to (i.e., delayed disengagement from) positive over competing negative material. Therefore, together with standard measures of attentional engagement with emotional information: time to move gaze from a neutral to a disgusted or happy face (32 trials, 16 of each emotional condition), and disengagement from emotional information: time to move gaze from a disgusted or happy face to a neutral face (32 trials, 16 of each emotional condition), a third condition was included, comprising viewing competing disgusted vs. happy faces (32 trials). This third condition served to index the main attention bias transfer measures in the study: 1) time to disengage attention from negative faces when prompted to engage with positive faces (16 trials), and 2) time to disengage attention from positive faces when prompted to engage with negative faces (16 trials). A fourth control neutral vs. neutral faces condition was also included (48 trials), where the neutral expression of the same actor was presented twice and participants had to move their gaze from one to the other exemplar to detect the frame. Corresponding disgusted, happy and neutral expressions in each condition were presented equally often on the left as on the right. Both types of frames were also equally likely to appear in the left and right positions in all conditions. The task also included 6 practice trials, followed by a brief pause before starting the actual trials. An overview of the trials' sequence and measures assessed at each phase and attentional component for the main indices in the study is depicted in Figure 3[1].

Criteria for identifying valid disengagement patterns were identical to previous research (see Sanchez, Vanderhasselt, et al., 2016). An average of 95% trials per participants (94% at pre-

[1] As part of a larger project, two "wait for fixation" periods were introduced in this study (see also Figure 3): in half of the trials the "wait for fixation" period was introduced at the beginning of the stimuli presentation (i.e., at the moment that participants made the first visual fixation in the corresponding target face a frame appeared surrounding the opposite face), whereas in the other half of the trials the frame appeared surrounding the opposite face once participants made a visual fixation in the corresponding target face after 3,000 ms of freely viewing the face pair (as in the original task; Sanchez et al., 2013). This served to decompose attention bias into two separate phases of processing, namely, early and late phases of emotional processing and to test their different associations with depression and anxiety symptom levels. These further results are available upon request. Since the current study did not make specific predictions regarding differential effects in early and late stages of attentional disengagement, we calculated aggregated scores to analyze the ECAT transfer effects in each of the two main attentional disengagement indices (i.e. from negative to positive, from positive to negative). Further details on specific early and late-stage attention indices, including those ones that were not part of the main variables in the study, are reported in the Supplementary material.

training, 96% at post-training) were identified as valid recordings. From those trials, attention bias indices were computed for each main variable of interest: 1) time to disengage attention from negative faces when prompted to engage with positive faces, and 2) time to disengage attention from positive faces when prompted to engage with negative faces. Internal consistencies for these indices were good both at the pre- and post-training assessments (disengagement from disgusted to happy: at pre-training α= .76, at post-training α= .77; disengagement from happy to disgusted: at pre-training α= .80, at post-training α= .79). Full details on descriptives, internal consistencies and training transfer effects for all the other attention bias indices assessed in the task are presented in the Supplementary material.

Reappraisal and Negative Emotions. The emotion regulation task employed in Sanchez et al. (2016) was again used to assess transfer to reappraisal and negative emotions (based on Vanderhasselt, Kühn, & De Raedt, 2013). The task involved the presentation of thirty-two negative IAPS pictures (Lang, Bradley, & Cuthbert, 2008) depicting depression-relevant themes (e.g., crying people, loneliness; further details in Sanchez et al., 2016). On each trial, a negative picture was presented and, after 2000 ms, participants rated their negative emotional experience on a 10-point scale (0 – 'not at all' to 9 – 'very much'). A cue subsequently prompted them to appraise or reappraise the picture's meaning. When instructed to appraise, participants were asked to look at the picture and freely experience the elicited feelings. When instructed to reappraise, participants were asked reinterpret the picture's meaning in a less negative way by changing the emotions, actions, and outcomes of individuals depicted in the picture (Ochsner, Bunge, Gross, & Gabrieli, 2002). After 10 s, participants' negative emotional experiences were reassessed using the same 9-point rating scale. When instructed to reappraise, participants also provided a description of how they reappraised the picture. In each assessment (i.e., pre- and post-training), half of the pictures were appraised and the other half reappraised. Pictures and regulatory instructions were randomly presented with the constraint that maximum 2 pictures with the same regulatory instruction occurred consecutively.

Reappraisal ability scores were computed using narrative descriptions provided by participants. Two blind raters evaluated whether participants were successful at generating reappraisals of negative scenes using a 5-point scale (0–No Description, 1–Not at all, 2–A little, 3–Good, 4–Very good). An intra-class correlation of .88 (p=.001) indicated high inter-rater agreement. Reappraisal scores were computed by averaging the blind raters' scores separately for the pre- and post-training emotion regulation tasks. Higher scores indicate better reappraisal. Furthermore, down-regulation of negative emotions was computed by averaging the emotion ratings indicating the degree of negative emotions after viewing pictures in the reappraisal trials.

State Rumination. Immediately after completing the emotion regulation task (both at pre- and post-training assessment), participants rated the extent to which they had ruminated while viewing the negative IAPS pictures. The measure of state rumination comprised five 10 cm visual analogue scales (VAS). The first two items (i.e., "I was focusing on my feelings", "I was focusing on my problems") comprised momentary assessments of ruminative self-focus found to be associated with state changes in negative affect (Moberly & Watkins, 2008). The three last items (i.e., "I was thinking about a recent situation, whishing it had gone better", "I was thinking: why do I have problems other people don't have?", "I was thinking: what am I doing to deserve this?") comprised momentary assessments of ruminative brooding adapted from the Ruminative Response Scale brooding scale (RRS; Treynor, Gonzalez, & Nolen-Hoeksema, 2003). These items were selected on the basis of a validation longitudinal study (Vanderhasselt et al., in preparation) indicating very good psychometric properties. In our study, the five items showed good internal consistency both at pre- and post-training: α = .73 and α = .72, respectively.

Eye-tracker

A Tobii TX300 eye-tracker recorded gaze behavior during the engagement-disengagement and ECAT tasks, with eye-gaze coordinates sampling at 300 Hz. Participants were seated approximately 60 cm from the eye tracker. Visual fixations were considered when longer than 100 ms. Stimulus presentation and eye movement recording were controlled by E-prime Professional software. E-prime extensions (TET and Clearview PackageCalls) converted eye movement signals to visual fixation data, and computed and presented fixation time scores in the training condition.

Analytic plan

First, a 2 (Condition: Training, Control) x 2 (Phase: Baseline, Modification) mixed-design repeated measures ANOVA with fixation times to positive over negative words as dependent variable, was conducted to test Hypothesis 1: namely, to test the expected effects of active ECAT in increasing attention to positive over negative words (i.e., attention regulation implementation) across the training procedure (i.e., from the baseline to the modification phase).

Then, consistent with the approach employed by Sanchez et al. (2016), we tested Hypotheses 2 to 5 focusing statistical analyses on the role of individual differences in the degree of attention regulation implemented following active ECAT (i.e., change scores in fixation times to positive over negative words from the baseline to the modification phase) when evaluating its hypothesized transfer to attentional disengagement, reappraisal, negative emotions and state rumination changes. Prior research has revealed marked individual differences in the malleability of attention mechanisms through training (Clarke, Chen, & Guastella, 2012; Clarke, Macleod, & Shirazee, 2008; Everaert et al., 2014). Therefore, as in Sanchez et al. (2016), individual differences in attention regulation implementation were indexed via residualized change scores (Segal et al., 2006). Fixation times to positive over negative words during the baseline phase were entered in a simple regression model as predictor of fixation times to positive over negative words during the modification phase. The resulting standardized residuals were saved and served as a measure of attention regulation implementation. In a similar way, changes in attentional disengagement indices, reappraisal ability, negative emotions, and state rumination were indexed by computing residualized change scores from the pre- to the post-training assessment for each of these measures separately. Each simple regression model regressed the post-training score on the pre-training score (i.e., time 1 score predict time 2 score), and the resulting standardized residuals of each regression model served as change scores.

Serial mediation models were then used to test the hypothesized effects of the ECAT condition (i.e. active training vs. control) on outcome change measures via attention regulation implementation. After testing the significance of the total and direct effects in each model, the significance of the indirect effects were tested using a 5000 samples bias-corrected bootstrapping procedure, with 95% bootstrap confidence intervals (Preacher & Hayes, 2008). The effect size of each indirect effect model was derived by computing partially standardized indirect effects, as indicated for models with dichotomous variables in which the two groups differ by one unit (i.e., 0 – Control condition, 1 – Active Training condition) (see Preacher & Kelley, 2011).

Results

Sample Characteristics

Table 1 presents descriptives on demographics and varibles assessed at pre-training. The participants in the control versus the training condition did not significantly differ in age, $t(64)=0.90$, $p=.37$, gender ratio, $\chi^2(1)=0.08$, $p=.78$, nor on any of the self-report measures, all t's <

1.61, all *p's* > .05. Participants in the control and training condition did not differ either in baseline levels of attentional control inhibition and switching functions, as measured by the mixed antisaccade task (all *F*'s < 1.95, all *p's* > .05, all $\eta_p^2 < 03$, full details in the Supplement).

H1: Training Effectiveness (ECAT condition → attention regulation implementation)

Table 2 presents descriptives on the main variables in the study. The 2 x 2 ANOVA revealed main effects of Condition, $F(1,64)=46.91$, $p=.001$, $\eta_p^2=.42$, and Phase, $F(1,64)=20.82$, $p=.001$, $\eta_p^2=.24$, as well as a Condition × Phase interaction, $F(1,64)=45.04$, $p=.001$, $\eta_p^2=.41$. Follow-up Bonferroni-corrected tests showed no differences between the conditions in total fixation times on positive over negative words at the Baseline phase, $F(1,64)=0.09$, $p=.76$, $\eta_p^2=.01$, but revealed significant differences after the Modification phase, $F(1,64)=76.95$, $p=.001$, $\eta_p^2=.55$, with participants in the training condition showing larger total fixation times on positive over negative words than participants in the control condition. As expected (H1), there was a significant increase in total fixation times on positive over negative words from Baseline to Modification phase in the training, $F(1,64)=63.55$, $p=.001$, $\eta_p^2=.50$, but not in the control condition, $F(1,64)=2.31$, $p=.13$, $\eta_p^2=.03$. Overall, results suggest that the active ECAT was effective in increasing attention regulation implementation in the expected direction.

Transfer of Training

H2: Transfer to attention disengagement (ECAT condition → attention regulation implementation → attentional disengagement change). As for *attentional disengagement from negative to positive information*, the serial mediation model with ECAT condition (i.e. criterion: training vs. control) on residualized changes in attentional disengagement from negative to positive information (i.e., outcome) via attention regulation implementation (i.e., mediator) showed that neither the total effect, c=-.07 (*SE*=.24), *t*=-0.28, *p*=.78, 95%-CI: [-.5603, .4227], nor the direct effect, c'=-.55 (*SE*=.36), *t*=-1.53, *p*=.13, 95%-CI: [-1.2651, .1663], were significant. The indirect effect (coefficient=.48, *SE*=.28) was neither statistically different from zero, 95%-CI: [-.0267, 1.0859], therefore not supporting this model.

As for the *attentional disengagement from positive to negative information*, a similar serial mediation model with attentional disengagement from positive to negative information change as outcome showed that neither the total effect, c=-.26 (*SE*=.24), *t*=-0.07, *p*=.29, 95%-CI: [-.7480, .2269], nor the direct effect, c'=-.70 (*SE*=.35), *t*=-1.97, *p*=.06, 95%-CI: [-1.4155, .0093], were significant. However, the indirect effect was positive (coefficient=.44, *SE*=.22) and statistically different from zero, 95%-CI: [.0298, .8676], supporting the model. The partially standardized indirect effect of the model was .44 (*SE*=.21; 95%-CI: [.0127, .8388]), showing that the active ECAT was associated with increases of 0.44 standard deviations in the time to disengage attention from positive information (i.e., sustained attention in happy faces) when prompted to engage attention with negative information, via its effect on attention regulation implementation.

H3: Transfer to reappraisal (ECAT condition → attention regulation implementation → attentional disengagement change → reappraisal change). The total effect, c=.19 (*SE*=.24), *t*=0.80, *p*=.42, 95%-CI: [-.2981, .6859], and direct effect, c'=.17 (*SE*=.36), *t*=0.47, *p*=.64, 95%-CI: [-.5596, .9034], were not significant. The indirect effect was positive (coefficient=.11, *SE*=.08), and statistically different from zero, 95%-CI: [.0035, .3291]. The partially standardized indirect effect of the model was .11 (*SE*=.08; 95%-CI: [.0019, .3204]). Thus, active ECAT was indirectly associated with 0.11 standard deviations of reappraisal improvement via its effect on attention regulation implementation and increases in attentional disengagement from positive to negative.

H4: Transfer to negative emotions (ECAT condition → attention regulation implementation → attentional disengagement change → reappraisal change → negative emotions change). The total effect, c= -.12 (*SE*=.24), *t*= -0.50, *p*=.61, 95%-CI: [-.6141, .3676], and direct effect, c'=.02 (*SE*=.35), *t*=0.74, *p*=.94, 95%-CI: [-.6704, .7223], were not significant. The indirect effect was negative (coefficient =-.05, *SE*=.04) and statistically different from zero, 95%-CI: [-.1866, -.0029]. The partially standardized indirect effect was -.05 (*SE*=.04; 95%-CI: [-0.1759, -.0023]). Thus, supporting the indirect model found in Sanchez et al. (2016), active ECAT indirectly led to decreases by 0.05 standard deviations in negative emotion after reappraisal (i.e., better emotion regulation), via its influence in attention regulation implementation, the influence of attention regulation implementation on increases in the time to disengage gaze from positive to negative faces, the influence of this attention mechanism on reappraisal change, and the influence of reappraisal change on negative emotion change.

H5: Transfer to state rumination (ECAT condition → attention regulation implementation → state rumination). Neither the total effect, c=-.28 (*SE*=.24), *t*=-1.14, *p*=.26, 95%-CI: [-.7657, .2080], nor the direct effect, c'=.16 (*SE*=.35), *t*=0.45, *p*=.65, 95%-CI: [-.5519, .8715], were significant. The indirect effect was negative (coefficient= -.44, *SE*=.21) and statistically different from zero, 95%-CI: [-.8583, -.0287], supporting the model. Partially standardized indirect effect of the model was -.44 (*SE*=.21; 95%-CI: [-.8551, -.0182]), showing that active ECAT was associated with decreases of 0.44 standard deviations in the use of ruminative thinking during the emotion regulation task, via its effect on attention regulation implementation. An overview of supported models is depicted in Figure 4.

Conclusions

This study aimed to replicate and extend evidence on how attention regulation, trained through a novel eye-gaze contingent attention training (ECAT), would influence attention biases, reappraisal success, and state rumination. There are several key findings: First, attention regulation implementation via active ECAT was evidenced by increases in the time fixating positive over negative words in the active training group, therefore, supporting H1 and replicating findings reported by Sanchez et al. (2016). Second, ECAT effectiveness (attention regulation implementation), in turn, accounted for indirect effects of the intervention in attention bias changes, as measured in the engagement-disengagement task (H2). Finally, ECAT had indirect effects in both improved reappraisal capacities (H3) and related improved regulation of negative emotions (H4), replicating the model found by Sanchez et al., (2016), as well as in decreased state rumination (H5). In all cases, the extent to which attention regulation was implemented during active training was a mediator of ECAT transfer effects in emotion regulation processes. We discuss these effects below.

Sanchez et al. (2016) reported ECAT transfer effects on increases in attention bias to positive over negative information, as indexed with a composite measure based on reaction times in the dot-probe task. Yet, it is important to note that trained attention regulation implementation during ECAT required both disengaging attention from negative information and increasing attention towards positive information while viewing competing negative vs. positive stimuli. Therefore, in the current study we obtained direct estimations of gaze behaviour towards and away from positive and negative information, in order to clarify specific attention mechanisms targeted via ECAT. Our results indicate that participants in the training condition who showed more attention regulation implementation (i.e., larger increases in fixation times on positive over negative information during active ECAT) showed longer times to disengage attention from happy faces when prompted to move their gaze towards disgusted faces. In contrast, no effects were found in the times to disengage attention from disgusted faces in order to move gaze towards happy faces. Therefore, the current findings point to a specific role of ECAT in improving sustained attention on positive information, rather than also improving an efficient attentional disengagement from negative counterparts. Yet, it is possible that the absence of transfer effects in the index of negative information disengagement might be in part accounted for by floor effects in our study. Our sample consisted of healthy undergraduate students, with low depressive and anxiety symptom levels (see Supplement), which might have reduced the chance to find decreases in this attention component. It has been previously shown, using the engagement-disengagement task (Sanchez et al., 2013), that clinically depressed individuals compared to healthy controls are characterized by longer times to disengage attention from negative faces. Moreover, a higher magnitude in such disengagement impairment was predictive of lower recovery from negative mood in response to a stressor (Sanchez et al., 2013). No marked impairments in attentional disengagement from negative information in our sample might account for the absence of transfer effects in this component. Further studies need to test whether training attention regulation with our ECAT procedure may also lead to reductions the time to disengage attention from negative information in individuals typically characterized by such impairment (e.g., currently and formerly depressed individuals; De Raedt & Koster, 2010).

Our study also replicates and extends results from Sanchez et al. (2016), confirming that transfer effects in attention biases (i.e., increases in the time to disengage attention from positive information) transferred to successful reappraisal success, in turn decreasing negative emotions. Taken together, results from these two studies suggest that both covert (i.e., RTs on the dot-probe task) and overt (i.e., eye movement indices) attentional shifts maximizing processing of positive over negative information may be related to reappraisal success. Both covert and overt attention biases to positive information have been previously related to more adaptive regulation of transient negative mood states (Taylor, Bomyea, & Amir, 2011; Sanchez, Vazquez, Gomez, & Joormann, 2014). The results from our studies indicate that such a relation may be explained through the role of visual attention patterns in the implementation of more successful reappraisal strategies (as indicated by improved reappraisal ability and decreased negative emotions).

Furthermore, the present study extends the examination of transfer effects in Sanchez et al. (2016), by also examining whether attention regulation implementation also has an effect on state rumination. Consistent with this hypothesis, increased attention regulation accounted for an indirect effect of the training in reducing the amount of ruminative responses while viewing negative scenes during the emotion regulation task. Although these results suggest an influence of ECAT on both reappraisal and ruminative responses, they might also indicate different mechanisms of action of the training for each emotion regulation strategy. Whereas reappraisal change was primarily dependent on transfer of training to visual attention patterns (i.e., gaze disengagement from positive information), rumination change was directly associated to attention regulation implementation during the training. Although training-related attention regulation in our study involves a measure of external visual attention regulation, it might also reflect a broader repertoire of attentional control over internal processing (for an overview on the differentiation between external and internal attention processes, see Golomb & Turk-Browne, 2010). Together with the use of individualized feedback on attention allocation (in order to maximize trainees' regulation of their visual attention patterns), another critical ingredient in the ECAT is the use of specific contexts (i.e., the content of the scrambled sentences). In those specific contexts, trainees have to use processed information to construct positive self-referent meanings. This task requires constant updating of information in working memory (i.e., updating specific words and their order while unscrambling them, e.g., "am winner born loser a I", in order to form the target grammatically correct sentence in time, e.g., "I am a born winner"). Furthermore, this task requires inhibiting the activation of alternative internal self-representations in working memory that might hamper performance (e.g., "I am a born loser"). These two executive functions (updating and inhibition of internal representations in working memory; Miyake et al., 2000) are thought to be critical for emotional regulation, with impairments being linked to ruminative thinking (Jutta Joormann, 2006; Joormann & Gotlib, 2008). Consistent with this notion, interventions training these executive functions have shown effectiveness in reducing ruminative responses (e.g., Hoorelbeke, Koster, Vanderhasselt, Callewaert, & Demeyer, 2015; Siegle, Ghinassi, & Thase, 2007). Yet, Hoorelbeke et al. (2015) showed that, in contrast to ECAT, this alternative cognitive control training did not show beneficial effects on the use of reappraisal. Whether attentional control implementation trained by ECAT reflects regulation of emotional processing both in the external environment as well as of their internal representations in working memory, and whether such benefits may differentially transfer to reappraisal and rumination responses is an exciting possibility that will require further research.

Altogether, our findings have important clinical implications. Despite the availability of a wide range of interventions for affective disorders, existing protocols show limited effectiveness, highlighting the need for optimization (Cuijpers, Smit, Bohlmeijer, Hollon, & Andersson, 2010). Integrating our findings on the causal mechanisms underlying emotion regulation and emotional vulnerability, therefore, is an important step in exploring new treatment possibilities. The use of eye-tracking techniques, as we demonstrate, may be a relevant way not only to detect specific components affected in attention processes but also, more innovatively, to train precise components linked to depression. Therefore, implementing this promising ECAT procedure to train specific attentional impairments underlying depressive symptomatology and its recurrence, may ultimately provide a tool to consolidate stable remissions and prevent new episodes.

Nonetheless, despite the promising venues opened with this initial research, several limitations must be noted. As already mentioned, the non-clinical nature of our sample may have limited the ability to detect transfer effects in some attention mechanisms known to play a role in emotion dysregulation in clinically depressed samples (Sanchez et al., 2013). A second limitation refers to the effect sizes of the transfer effects in this study. Whereas the engagement-disengagement task allowed to clarify specific mechanisms involved in transfer effects to reappraisal success, the effect sizes of the indirect effect models were lower than the ones reported in Sanchez et al. (2016). This might be explained by the use of emotional faces instead of self-referent adjectives in the transfer task, as in Sanchez et al. (2016), since recent meta-analyses indicate that effects of attention bias modification procedures would be stronger for lexical than for visual stimuli (e.g., Beard, Sawyer, & Hofmann, 2012; Hakamata et al., 2010). Finally, despite the significant effects observed on decreased state rumination, overall state rumination levels in the experiment were rather low, limiting the generalizability of these effects to individuals characterized by a higher use of this maladaptive process. Again, the characteristics of our sample (with low symptom and trait rumination levels) might partly account for this issue. Yet, overall low levels of state rumination in the study might also be partly due to the fact that rumination responses were assessed during viewing negative scenes, for which half of them were required to be reappraised. Future studies need to use independent assessments of both reappraisal and rumination responses in order to better delineate the specific contribution of attention mechanism tacked by the training to each of these strategies.

Our study, together with evidence from Sanchez et al. (2016), provides clear evidence on the links between attention mechanisms, reappraisal success, and state rumination. The new ECAT procedure validated in these studies provides an important step to new personalized cognitive trainings of attention for depression.

Acknowledgements

This research was supported by a grant of the Research Foundation Flanders (FWO) awarded to the first author, a postdoctoral research fellowship from the Belgian American Educational Foundation (BAEF) awarded to the second author, and a grant BOF16/GOA/017 for Concerted Research Actions of Ghent University awarded to the last two authors. The first author is currently supported by the Program for the Attraction of Scientific Talent of the Community of Madrid. The authors declare no conflict of interest.

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Table 1. *Descriptive statistics for the pre-training measures in the study.*

	Training (N=33)		***Control (N=33)***	
Variables	*M*	*SD*	*M*	*SD*
Demographics				
Gender (male/female)	8/25		9/24	
Age	22.70	5.69	23.91	5.20
Baseline self-report measures				
Depressive symptoms (BDI-II: 0-63)	5.39	4.67	7.61	6.37
Anxiety symptoms (STAI: 20-80)	35.82	6.81	38.73	8.52
Trait Rumination (RRS: 22-88)	43.39	10.71	46.18	12.57
Trait Reappraisal (ERQ: 6-42)	27.97	6.28	26.39	6.83
Trait Resilience (RS: 25-100)	77.18	6.93	75.36	9.07
Baseline attentional control executive functions				
Inhibition cost for neutral (A-P diff)	28.51	59.11	16.18	58.09
Inhibition cost for positive (A-P diff)	15.18	60.78	5.65	65.22
Inhibition cost for negative (A-P diff)	18.32	62.59	1.85	66.00
Switch cost prosaccade for neutral (S-R diff)	9.45	32.50	23.10	27.12
Switch cost prosaccade for positive (S-R diff)	5.48	59.81	15.78	35.12
Switch cost prosaccade for negative (S-R diff)	19.00	36.93	8.41	34.28
Switch cost antisaccade for neutral (S-R diff)	-7.69	41.87	-2.91	35.63
Switch cost antisaccade for positive (S-R diff)	-1.33	63.53	-3.53	48.33
Switch cost antisaccade for negative (S-R diff)	-2.45	39.92	-6.91	39.59

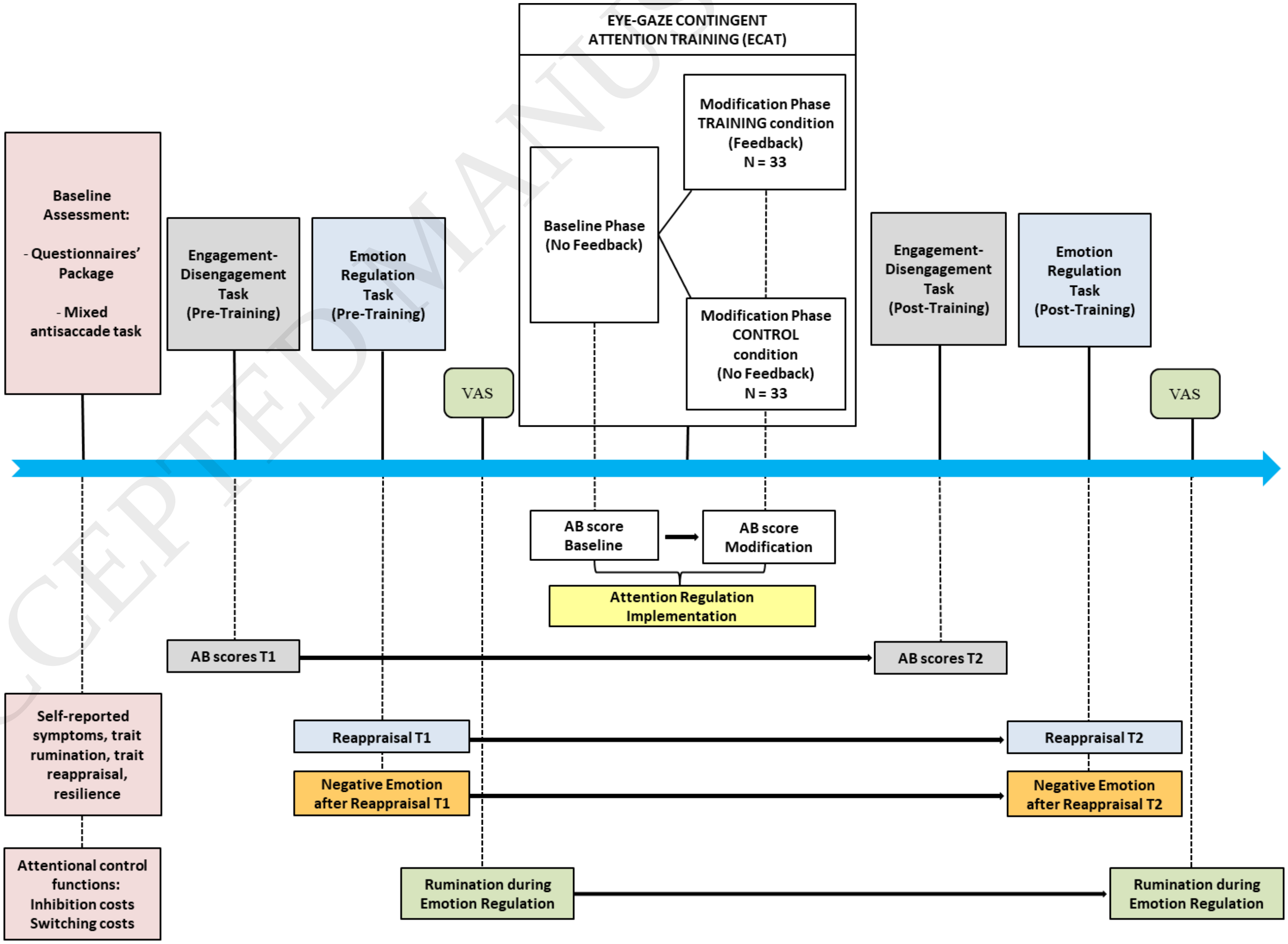
Notes. M = Mean; SD = Standard deviation; A-P diff = Difference overall antisaccade latency minus overall prosaccade latency, in ms; S-R diff: Difference switch trials latency minus repeat trials latency for the corresponding condition (i.e., prosaccade, antisaccade), in milliseconds.

Table 2. *Descriptive statistics for the main variables in the study*

Variables	***Training (N=33)***		***Control (N=33)***	
	M (SD)	*M (SD)*	*M (SD)*	*M (SD)*
Attention Regulation during ECAT	**Baseline Phase**	**Modification Phase**	**Baseline Phase**	**Modification Phase**
Time fixating on positive over negative words (prop)	0.52 (0.04)	0.61 (0.07)	0.52 (0.04)	0.50 (0.02)
Training transfer indices	**Pre-ECAT**	**Post-ECAT**	**Pre-ECAT**	**Post-ECAT**
Gaze disengagement from negative to positive (ms)	266.72 (58.69)	247.37 (36.62)	261.68 (43.20)	256.22 (37.41)
Gaze disengagement from positive to negative (ms)	276.02 (63.70)	253.31 (43.96)	267.50 (41.12)	256.24 (45.97)
Reappraisal (range 0-4)	1.74 (0.66)	1.99 (0.86)	2.05 (0.61)	2.11 (0.62)
Negative emotion after reappraisal (range 0-9)	4.79 (1.44)	3.82 (1.82)	4.82 (1.27)	4.00 (1.37)
State Rumination (range 0-10)	1.21 (0.75)	0.95(0.59)	1.20 (0.60)	1.08 (0.66)

Notes. M = Mean; SD = Standard deviation; ms = millisecond; prop = proportion; ECAT = Eye-gaze contingent attention training.

Figure 1. Schematic on the task sequence during the experimental session, and overview of indices computed in each task



Notes. IB = Interpretation bias; AB = Attention bias; T1 = Time 1 (pre-training); T2 = Time 2 (post-training), VAS = Visual analogue scale

Figure 2. Schematic overview of the ECAT procedure

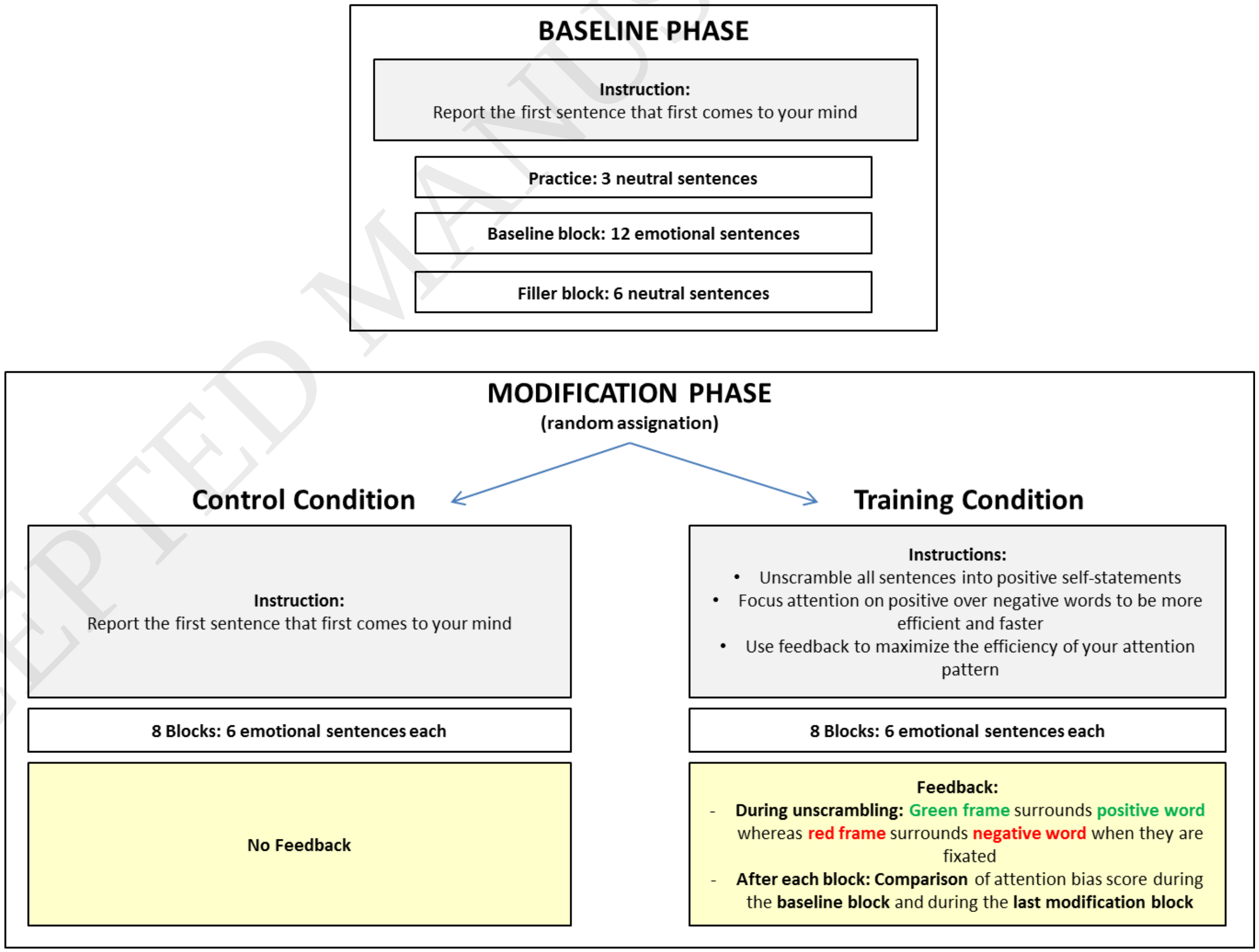


Figure 3. Trials' sequences and measures assessed at each phase and attentional component for the main indices in the engagement-disengagement task (averaged into main disengagement components in the main analyses).

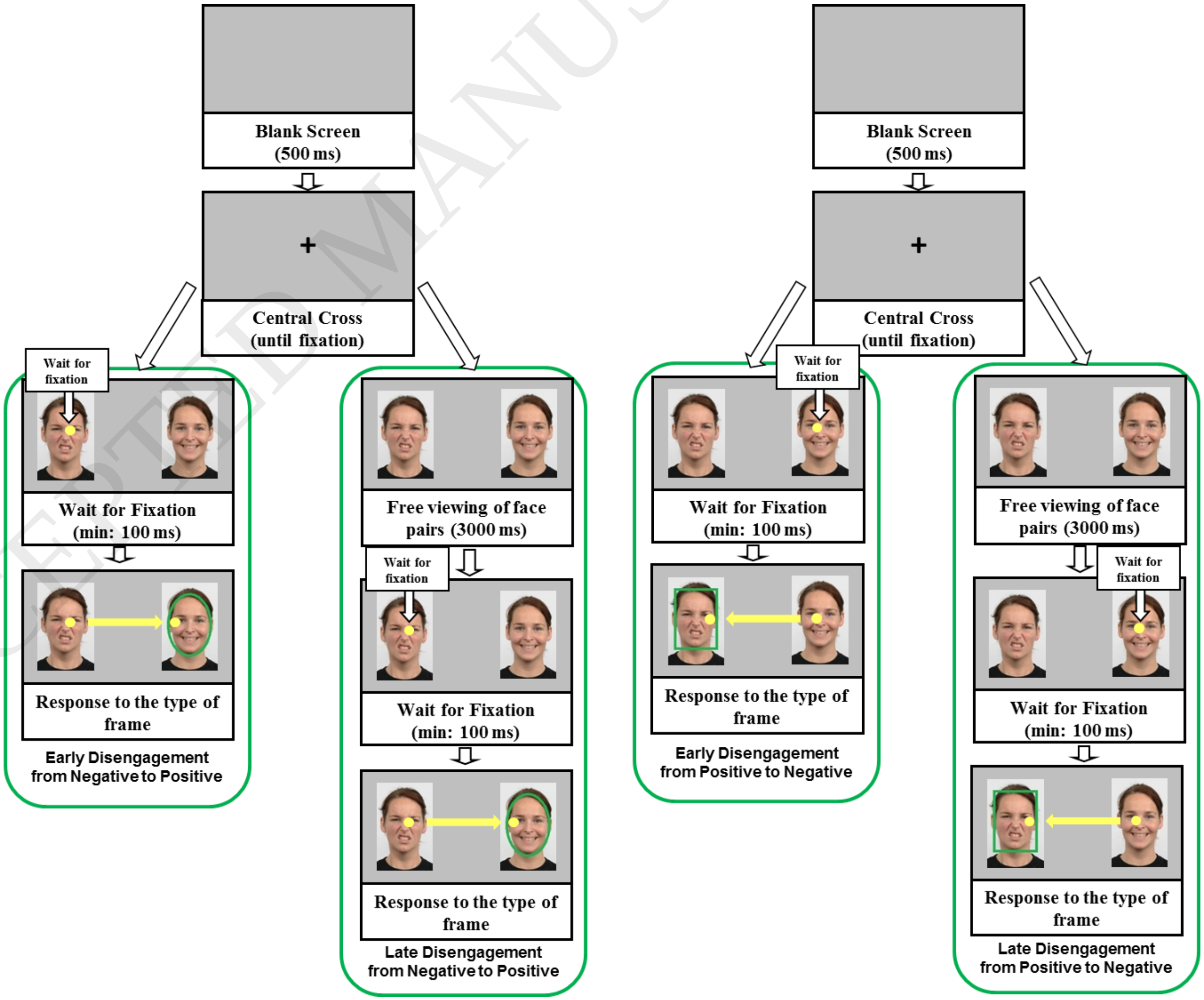


Figure 4. Overview of the main indirect effect models supported:

a) ECAT leads to increases in attention regulation implementation (in the training); larger attention regulation implementation leads to larger Attention Bias (AB) increase in the time to disengagement from positive to negative information; larger AB increase leads to larger reappraisal increases; larger reappraisal increases leads to larger reductions in negative emotion after reappraisal

b) ECAT leads to increases in attention regulation implementation (in the training); larger attention regulation implementation leads to larger reductions in state rumination